UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

District E

FINAL REPORT OF MAJOR MINE-EXPLOSION DISASTER
VIKING MINE
VIKING COAL CORPORATION
TERRE HAUTE, VIGO COUNTY, INDIANA

March 2, 1961

By

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INTRODUCTION

A gas and dust explosion occurred in the Viking mine of the Viking Coal Corporation, 5 miles northwest of Terre Haute, Indiana, about 7:30 p.m., Thursday, March 2, 1961, and caused the death of 22 men from suffocation, burns and/or forces. None of the remaining 33 men in the mine at the time of the explosion was injured, and they returned to the surface unassisted.

The names of the victims, their ages, marital status, occupations, and the number of their dependents are listed in Appendix "A" of this report.

Bureau of Mines investigators believe that the explosion originated at or near the intersection of the 4 north Right "B", and 8 east Right "A" entries in the 4 north section off the north-west angles when an explosive mixture of methane-air was ignited by an electric arc or

spark from electrical equipment or an open flame, and that the explosion was propagated by methane and coal dust.

Forces of the explosion radiated from the junction of the 4 north Right "B" entry, and 8 east Right "A" entry and spread left and right into the worked-out 7 and 6 east sections, the active 7 west section and the temporarily idle 8 west section and extended to about 250 feet outby the 5 east section in the 4 north entries off the north-west angles.

GENERAL INFORMATION

The Viking mine is located on the Bolton Road, 5 miles northwest of Terre Haute, Indiana, and 2 miles east off U. S. Highway 150, in Vigo County. All coal produced in the mine is conveyed by a series of belts directly to the Public Service Company of Indiana, Incorporated, Wabash Generating Station which adjoins the mine property. The operating officials of the company on March 2, 1961, were as follows:

W. S. Webster	President	Terre Haute, Indiana
Birch Brooks	Vice President and General Manager	Terre Haute, Indiana
C. B. Burk	General Superintendent and Mining Engineer	Terre Haute, Indiana
Stewart Johnson	Superintendent	Terre Haute, Indiana
Jesse Shepperd	Mine Manager (Mine Foreman)	Farmersburg, Indiana
Henry J. Robertson	Night Mine Manager	Terre Haute, Indiana
Ray Biggs	Electrical Engineer	Rosedale, Indiana
Morris Adams	Chief Electrician	Rosedale, Indiana

On March 1, 1961, a total of 190 men was employed; 24 on the surface and 166 underground on two coal-producing shifts and a maintenance crew on the third shift. The average daily production was 2,733 tons of coal and production for the year 1960 was 664,080 tons. The mine is opened by two concrete-lined shafts 186 and 256 feet in depth and a 27.5 percent concrete-lined slope 455 feet in length. The workings are in the Indiana No. 5 coal bed, which averages 48 inches in thickness in the present active workings and dips slightly to the west by southwest.

The immediate roof is a very hard layer of sandy shale locally known as the "steel band" which is 4 to 8 inches in thickness, overlaid by 24 to 36 inches of hard black shale and about 48 inches of hard gray shale, successively. The floor is a smooth, soft fire clay that disintegrates when exposed to the atmosphere.

The analysis of a coal sample from the Indiana No. 5 coal seam in this mine, as provided by the company is as follows:

	Percent
Moisture	10.19
Volatile Matter	34.05
Fixed Carbon	41.00
Ash	14.76
	100.00 percent

Numerous tests conducted by the Bureau of Mines have shown that coal dust having a volatile ratio of 0.12 is explosive and that the explosibility increases with an increase in the volatile ratio. The volatile ratio of the coal in this mine as determined from the afore-mentioned analysis is 0.45, indicating that the dust from this coal is explosive.

The last Federal inspection of this mine prior to the disaster was made December 5-8 and 12-13, 1960.

MINING METHODS, CONDITIONS, AND EQUIPMENT

Mining Methods: The mine was developed by a panel, room-and-pillar system and pillars were not extracted, except that partial extraction (slabbing) of room pillars was being done in the "Colmol" sections. Main entries were driven in sets of six, 14 feet wide, on 40- and 45-foot centers. Room-panel entries were driven 14 feet wide, on 40- and 50-foot centers in sets of three at various intervals and branching off to five entries at Room 1. Rooms were driven 18 to 22 feet wide on 40- and 50-foot centers and crosscuts were generally 45 to 60 feet apart.

The Indiana Nos. 3 and 4 seams underlie the Indiana No. 5 seam and mining therein done by another company resulted at times in subsidence in the No. 5 seam and immediate roof strata. Such subsidence had occurred in the past in the 4, 5, 6 and 7 east and the 4, 5, and 6 west room-panel entries off 4 north. When subsidence does occur, dangerous roof is encountered, there is a definite depression in the bottom, the unmined roof coal draws away from the shale roof, the coal is broken down with compressed air more easily in conventional mining sections, the "Colmol" penetrates the coal more readily and with far less difficulty and methane may or may not be liberated. When methane is liberated it bleeds off very rapidly due to the ample quantity of air generally sweeping the working faces. Extensive timbering is required at places where subsidence is encountered.

A standard plan of permanent timbering was in effect and was followed in rooms which required one row of posts to be set on one side of shuttle-car roadways on 4-foot centers to within 12 feet of the faces. In addition to conventional timbering in rooms, roof bolts were installed in clusters at places where doubtful roof was encountered. The roof in entries generally is considered self-supporting and the installation of roof bolts was not in sequence with the mining cycle. When doubtful roof is encountered in entries the working places are stopped and equipment removed until the condition is corrected.

Two loading-machine units in the main west section and two continuous-miner units were operated during each of the two coal-producing shifts during the last inspection and at the time of the explosion three continuous-miner units and one loading-machine unit were being operated on each coal-producing shift.

Blasting: All coal in the conventional mining sections was undercut by rubber-mounted cutting machines and broken down on shift by means of compressed air. Any necessary rock blasting was done off shift with permissible explosives.

Ventilation and Gases: The mine was ventilated by means of two axial-flow fans, operated exhausting and circulating approximately 163,000 cubic feet of air a minute. The fans were operated continuously and were installed on the surface in fireproof structures, offset a suitable distance from the shafts, and were equipped with the necessary safety devices, such as explosion doors, pressure-recording gages, and alarms

to give warning if the fans slow down or stop. Each fan is equipped with an auxiliary drive unit to operate the fan in the event of electric power failure. Overcasts, seals and permanent stoppings were constructed of incombustible material. Temporary stoppings, check curtains, and line brattice were used to conduct air in the face regions. However, the day of the explosion a line brattice was not used in the 7 west Right "A" entry off the 4 north Left "C" entry, and the line curtain in 8 east Right "A" off the 4 north Right "B" entry was taken down and used in the 4 north Right "B" entry. Ventilation doors were generally installed in pairs, and single, supply doors had been installed in the 7 and 8 west sections off 4 north. The second or inby doors in the 6 and 7 east sections were taken down when recovering material from these sections, thereby nullifying the air locks.

A split system of ventilation was used in this mine. The No. 1 fan was exhausting 96,000 cubic feet of air a minute and it ventilated the main west section, including the north-west angle entries, the slope to the bottom of the No. 2 coal-storage bin, the idle southwest section and most of the seals on both sides of the north-west angle entries. The No. 2 fan was exhausting 67,000 cubic feet of air a minute and this volume of air was divided into two primary splits. The larger split of air was used to ventilate the active workings in the 4 north off the north-west angles (the explosion area) and a small split of air was used to ventilate the seals at the mouth of 7 main west off the north-west angles. The intake air entered the mine through the main slope and through one

of the compartments of the No. 2 air shaft and circulated to the active, idle and abandoned sections through the main haulage and parallel entries. The ventilating current circulated through the active workings and was then used to ventilate worked-out panel entries, and then passed directly into the main return airways. The quantity of air reaching the last open crosscut in each set of entries during the last Federal inspection in December 1960, ranged from 7,000 to 20,000 cubic feet a minute.

The following air measurements and methane determinations were made during the December 1960 Federal inspection:

Location	Volume of air, c.f.m.	Methane percent	Cubic feet of methane in 24 hours
Total return, at bottom of No. 1 upcast shaft	96,000	0.06	83,000
Return 6 east off 4 north, NWA, 20 feet inby 4 north Right "B" entry	21,230	0.09	28,000
Return of 7 east section off 4 north at intake to 6 east, NWA	13,000	0.07	13,000
Total return, at bottom of No. 2 upcast shaft	67,000	0.07	68,000
Return of 3 north off main west 20 feet inby mouth of main west Right "B" entry	10,700	0.04	6,200

The weekly air measurements in cubic feet per minute for the month of February were as follows:

	Date 2/3	Date 2/10	Date 2/17	Date 2/24
Downcast	114,000	114,950	112,100	114,000
Upcast	113,400	113,140	113,900	112,140
Main west, south	9,180	9,180	9,180	9,180
4 north, main west, north	10,200	12,000	10,800	9,600
3 north, main west, north (R.)	8,400	7,200	7,800	8,400
3 north, main west, north (L.)	8,400	7,500	8,400	8,400
1 east, 3 north, main west, north	9,900	9,000	11,400	10,200
Main west, north	22,800	21,000	19,200	21,000
Explosion area				
7 west, 4 north, north-west angles	13,380	13,800	13,800	13,860
8 west, 4 north, north-west angles	13,260	13,620	13,560	13,440
4 north, north-west angles (R.)	13,200	13,200	12,000	13,080
4 north, north-west angles (L.)	12,000	12,600	12,960	13,200
North-west angles - Airshaft Downcast	78,400	77,490	78,890	78,120
North-west angles - Airshaft Upcast	57,680	58,296	57,792	57,288

The mine is classed gassy by the Indiana Bureau of Mines and Mining and by the Bureau of Mines. Preshift, on-shift, and weekly examinations were made for gas and other hazards by certified officials, and the results of these examinations were recorded. Methane had not been

reported in any of the workings by the certified officials for the previous month, and gas had not been reported during the past three Federal inspections of the mine.

Operators of electrical face equipment were instructed by management to make suitable tests for gas before such equipment was taken to the working faces and frequently while the equipment was being operated at the faces. However, during a hearing held by the State officials on the investigation of the disaster it was learned that the continuous-miner operators generally depended on the tests made by the foreman. Normally, tests were made for gas after pulling the machine back out of each box cut or when bit changes were made, which was about every 20 or 30 minutes. All the flame safety lamps found in the explosion area were damaged. Evidence indicated the continuous-miner operator in the 7 west section did not have a flame safety lamp on the night of the explosion.

There were no oil or gas wells penetrating the coal bed in the area being worked, but a dry well had been drilled through a solid block of coal 500 feet south of the abandoned 2 main south entries off 3 main west. The dry well was plugged by the drilling company with 50 feet of concrete above and below the No. 5 coal seam and when mining is resumed in this area it will be protected by a block of coal at least 100 feet in diameter.

During the last Federal inspection, five air samples were collected in open workings at points not less than 12 inches from the roof, face, and rib, and the methane content of these samples ranged from 0.04

to 0.09 percent. A total of approximately 151,000 cubic feet of methane was being liberated every 24 hours. The carbon dioxide content ranged from 0.09 to 0.13 percent and the oxygen from 20.67 to 20.81 percent.

Dust: Most of the mine surfaces were dry, but the roof, ribs, and floor of all rooms, haulage, parallel, and back entries were rock-dusted to within less than 40 feet of the faces including all open crosscuts at the conclusion of the last Federal inspection and the mine was well rock-dusted and reasonably free of loose coal and coal-dust accumulations at that time. Water sprays were used to allay the coal dust during dumping operations at the storage bins located at the bottom of the two slopes and during the operation of the continuous miners. Water was injected into boreholes before breaking down coal with compressed air. Calcium chloride was used to allay the dust on shuttle-car roadways in the working sections, and water was used occasionally to allay the dust on main haulage roads. No method of allaying the dust was used during cutting and loading in the conventional mining sections.

Normal practice was to rock dust by hand daily in the working places and additional rock dust was applied by machines every other day in each working section.

During the December 1960 inspection the main west entries were sampled intensively, according to a fixed pattern, at regular intervals. Four of the 34 dust-survey samples and three of the 13 random mine-dust samples contained less incombustible material than was required for this mine, and all substandard areas were rerock-dusted promptly.

After the explosion, examinations in the explosion area revealed that the sections were covered with a layer of coal dust and/or soot, which was thickest near the faces of the 4 north entries along the belt and parallel entry and near the faces of the 7 west entries. Outby these areas, the deposit became thinner as the explosion forces were dissipated in traveling out the 4 north entries. There was evidence that the explosion area had been rock-dusted, but the applications were not heavy enough in the 4 north section to stop propagation of the explosion. The 8 west section had not been rock-dusted. Excessive accumulations of coal dust were observed in the 7 west entries, in the face regions of the 4 north and 8 east entries and along the 4 north belt and parallel entries.

Rock dusting of the areas was the principal factor in preventing further spread of the explosion, and during the investigation 40 mine-dust samples were collected in the areas affected by the explosion forces (see Table 2). Eleven of the twelve samples collected in the 7 west entries, three of the samples collected in 8 west and 15 of the 24 samples collected in the 4 north set of entries contained less than 65 percent incombustibles. A sample containing 34.1 percent of incombustible material was collected at the face of 7 west Right "A" entry principally for the coke content. The samples with sufficient incombustibles were collected in the areas where the explosion forces were weakest. However, the mine-dust samples collected were not representative of mine dust conditions prior to the explosion, as coal dust thrown into suspension and deposited on rock-dusted surfaces increased the combustible content.

Transportation: Thirteen-ton, General Electric, trolley locomotives were used to haul the 5-ton, all-steel, drop-bottom-type mine cars on the main-line haulage roads. Eight-ton, Goodman, trolley locomotives were used on the secondary and gathering haulage roads. Several company-constructed jeeps were available for transportation of mine officials, electricians, repairmen and visitors.

Type 76 AM Jeffrey Colmols were used to mine the coal in the 4 north off the north-west angles which included the 7 west and 4 north working sections. The coal was dumped onto the floor by the Colmols and picked up by permissible-type Joy 14BU loading machines and then loaded into permissible- and nonpermissible-type Joy 6SC shuttle cars. Loading machines were used not only to remove the coal from behind the Colmols but also to obtain better clean-ups in the working sections. The coal was then dumped onto belts and thence conveyed directly to the mine cars.

Electricity: Electric power at 2,300 volts alternating current entered the mine through two cased boreholes; the borehole cables were neoprene jacketed type. The primary power was transformed to 480 volts for continuous miner (Colmol) and auxiliary equipment by 300 kv.-a dry-type transformers, connnected delta/wye, with the wye neutral utilized for frame-grounding. Power was transmitted to the Colmol by type PCG and type G trailing cables listed by the Bureau of Mines as fire resistant. Type PCG cables were used from the transformer to a permissible distribution box, with the PCG circuit affording a constant ground continuity check. Power from the distribution box to the Colmol was transmitted by

a type G cable with the ground solidly attached to the Colmol frame. Ground-fault protection was provided by window-type current transformers at the distribution box and a conventional impedance-delay relay and window transformer setup at the power transformer, with a cascading effect allowing the distribution box to "out" under ground-fault conditions before the power transformer main secondary breaker. Overcurrent protection was provided by thermal-magnetic breakers at the power transformer, distribution box and Colmol. No electrical faults could be found on any face equipment or the trailing cables during the investigation.

Direct-current power at 275 volts was converted from the primary 2,300-volt alternating current by motor generators and rectifiers, each rated at 300 kilowatts. Direct-current power was used for all coal transportation and face equipment other than the Colmols. Direct-current power wires were installed on insulators and cut-out switches were installed where needed. Trailing cables on mobile equipment were approved as fire resistant and provided with short-circuit protection at the nip ends. All trailing cables except those on the Colmols contained several temporary splices but a check of the cables for continuity indicated the splices were well made mechanically and electrically. Face equipment was of a permissible and nonpermissible type. Permissible equipment in the active faces of the explosion area consisted of two Jeffrey MM 76 AM Colmols and two Joy 14BU - 7RBE loaders; nonpermissible face equipment in this area consisted of four Joy 6SC shuttle cars.

The face electrical equipment was examined in the 7 west and 4 north sections after the explosion by two coal company chief electricians

and a Federal coal-mine inspector (electrical), and the following defects were noted: The 7 west Colmol had one Allen cap screw loose due to faulty threads on the contactor panel enclosure cover; the 7 west 14BU loader had a hole burned in the outside endbell of the left-hand head motor, the left-hand contactor panel enclosure had a 1/8-inch opening completely around its circumference, the tram motors controller enclosure had a 0.012-inch opening on the cover and the trailing cable bellmouth entrance gland into the tram controller had a large opening burned into it; the 4 north Colmol had a 0.006-inch opening along the upper and lower inside joint between the contactor panel enclosure and cover, the right-hand cutting motor had only a very short piece of asbestos packing in the cable entrance gland thus leaving an opening around the entrance cable; the 4 north 14BU loader had a large opening burned into the tram controller enclosure at the bell-mouth trailing cable entrance gland, and the right- and left-hand contactor panel enclosures had approximately 1/8-inch openings completely around their circumferences. The nonpermissible shuttle cars had numerous openings into arcing electrical components; these were purchased prior to July 16, 1952, and not maintained as permissible on that date.

The face equipment in the 4 north was found to be parked and all controllers in the "off" position. The Colmol cable was found disconnected at the junction box, and the other trailing cables were apparently energized. It could not be determined whether the Colmol cable was disconnected before or by the explosion. The face equipment in the 7 west section was found to be in their respective coal-loading positions with

the Colmol controls in a mining position, the 14BU loader controls in an outward tram position and the inside shuttle car in an inward tram position. The Colmol continued to mine forward after the explosion until the arms became choked with coal and the caterpillar chains lost their grip and operated thus until the unharmed alternating-current power switch was pulled by the night mine manager. The 14BU loader and shuttle car ran together and their tramming mechanisms continued to operate for the short time the explosion force took to destroy the direct-current power lines.

Illumination and Smoking: Permissible electric cap lamps were used for portable illumination underground, and fixed electric lights were installed at underground shops, at belt heads and along haulage roads at frequent intervals. Smoking was not observed underground at the time of the last Federal inspection. However, smokers' articles were listed among the personal effects of many of the explosion victims including the foremen. An opened pack of cigarettes was found in each of the two affected sections, and a lighter was found about 115 feet outby the 7 west belt head. The underground employees were not searched for smokers' articles before entering the mine.

Mine Rescue: A mine rescue team was not maintained at the mine; however, four officials and four workmen received initial mine rescue training on April 7, 1956. Two officials are active members of one of the two fully equipped mine rescue teams trained by the Inspectors of the Lynch Coal Operators Reciprocal Association for the Indiana coal operators. The Indiana Bureau of Mines and Mining and the Lynch Coal Operators Reciprocal

Association maintain fully equipped rescue stations at Terre Haute and Bicknell, Indiana. Each rescue station is equipped with the necessary gas-detection devices, McCaa 2-hour self-contained oxygen breathing apparatus, Chemox 3/4-hour oxygen-generating breathing apparatus, and all-service gas masks. Many of the men in the face regions were equipped with self rescuers, and two all-service gas masks are kept in each working section for emergency purposes. Two travelable escapeways, one of which was in intake air, were provided from each working section to the surface. A check-in and check-out system was in effect, and all the men carried positive means of identification on their person while underground.

Adequate fire-fighting facilities were provided in the mine. Suitable fire extinguishers were kept in each working section, at each electrical installation, at tail end and head of conveyor belts and along the belt lines. A water pipe line equipped with outlets and hose was installed in the 7 west section off 4 north, two 800-gallon water-tank cars were kept filled at the slope bottom and 600 feet of 2½-inch and 300 feet of 1½-inch fire hose with suitable adapters were kept readily available. Rock-dust stations were provided at doors and at strategic locations throughout the mine.

STORY OF EXPLOSION AND RECOVERY OPERATIONS

Participating Organizations: These included the Viking Coal Corporation, the United Mine Workers of America, the Indiana Bureau of Mines and Mining, the Lynch Coal Operators Reciprocal Association and the U. S. Bureau of Mines.

Eight members of the two active Indiana coal operators mine-rescue teams composed of officials and workmen from the following coal companies assisted with the recovery operations:

Enoco Mine, Enoco Collieries, Inc., Bicknell, Indiana

Thunderbird Mine, Thunderbird Collieries Corporation, Farmersburg, Indiana

Green Valley Mine, Snow Hill Coal Corporation, Terre Haute, Indiana

Viking Mine, Viking Coal Corporation, Terre Haute, Indiana

Activities of Bureau of Mines Personnel: Charles Purcell, Director, Indiana Bureau of Mines and Mining, notified Fred Conrad, Lynch Coal Operators Reciprocal Association, Vincennes, Indiana, of the explosion about 10:00 p.m., Thursday, March 2, 1961. He in turn was asked by Mr. Purcell to contact the district supervisor of the Bureau of Mines, F. J. Smith, immediately and inform him of the occurrence. Mr. Smith then relayed the information to other Bureau of Mines personnel. Messrs. Smith, McCune, Lorenzo, and Dovidas arrived at the mine about 12:10 a.m., March 3. James Westfield, Assistant Director--Health and Safety, and Charles Ferguson, Director, Safety Division, United Mine Workers of America arrived from Washington, D. C., about 5:00 a.m., March 3.

Inspectors McCune, Lorenzo, and Dovidas entered the mine immediately after being briefed on the location of the explosion area and on underground and surface activities, and assisted in the recovery of the bodies.

The bodies of the 22 victims were recovered at various times during the night of March 2 and the morning of March 3, the last body reaching the surface about 7:35 a.m., March 3. (Appendix C)

Mining Conditions Immediately Prior to the Explosion: The weather on March 2 was warm and cloudy with overcast skies, and the temperature at Terre Haute, Indiana, ranged from a low of 34 degrees to a high of 61 degrees, Fahrenheit.

Records of barometric pressure recorded at the Terre Haute airport about 10 miles by air from the mine on March 1 and 2, 1961, are as follows:

Barometer Readings, March 1 and 2, 1961

29.92 Standard Reading -- Mine Uses Same Reading 29.92

	Time	Barometric pressure	Time	Barometric pressure
March 1 --	Noon	30.09	7:00 P.M.	30.06
	1:00 P.M.	30.06	8:00 P.M.	30.06
	2:00 P.M.	30.04	9:00 P.M.	30.05
	3:00 P.M.	30.03	10:00 P.M.	30.06
	4:00 P.M.	30.03	11:00 P.M.	30.05
	5:00 P.M.	30.04	Midnight	30.04
	6:00 P.M.	30.04		
March 2 --	1:00 A.M.	30.04	1:00 P.M.	29.86
	2:00 A.M.	30.04	2:00 P.M.	29.83
	3:00 A.M.	30.03	3:00 P.M.	29.80
	4:00 A.M.	30.00	4:00 P.M.	29.80
	5:00 A.M.	30.00	5:00 P.M.	29.79
	6:00 A.M.	30.02	6:00 P.M.	29.80
	7:00 A.M.	30.04	7:00 P.M.	29.81
	8:00 A.M.	30.01	7:30 P.M.	Time of explosion
	9:00 A.M.	29.99	8:00 P.M.	29.84
	10:00 A.M.	29.96	9:00 P.M.	29.85
	11:00 A.M.	29.94	10:00 P.M.	29.86
	Noon	29.90		

The accepted standard barometer reading at the airport and at the mine is 29.92. At noon on March 1, 31½ hours prior to the time of the explosion, the recorded barometric pressure was 30.09 from which point it continued to drop gradually until a low of 29.79 was recorded at 5:00 p.m., about 2½ hours prior to the time of the explosion. The recorded barometer reading a half hour before and after the time of the explosion was 29.81 and 29.84, respectively. It is believed the slight change in atmospheric pressure was not a contributing factor in the explosion.

The mine was in operation at the time of the explosion and had been in continuous operation since the 12 midnight to 8:00 a.m. shift started the previous Monday, February 27, 1961. The two fans were operating and the mine examiners did not record any unusual conditions in the mine.

Evidence of Activities and Story of Explosion: At the beginning of the 4:00 p.m. to 12 midnight shift on March 2, 55 men entered the mine, and they either walked or were transported in specially constructed, covered, man-trip cars to their respective working areas. The underground employees reached their working sections without mishap, and all the coal-producing workmen had been in the face regions approximately 3 hours when the explosion occurred. Conditions found after the explosion indicated that coal was being produced in each section in the usual manner. Preshift examinations had been made for the on-coming shift in the 4 north section of the mine, which included the 7 west and 4 north working sections. Methane was not reported and the air was traveling in its normal course and quantity. Methane had not been reported in the 4 north section for the past month.

Henry Robertson, the certified mine manager on the 4:00 p.m. to 12 midnight shift, entered the mine just prior to the start of the shift and by 4:10 p.m., after issuing last-minute instructions to workmen and the section foremen, returned to the surface. Jesse Shepperd, the mine manager (mine foreman), requested Mr. Robertson to return to the surface after the man-trips left the bottom for a short conference in which they discussed work to be done south of the bottom and for the repair or replacement of a broken rail in the main west. After giving specific tasks to the men working around the bottom and assigning men to erect a crib in the air course south of the bottom, Robertson returned to his underground office. He then issued instructions to a workman to take a small cable into the main west section and to take Norman Price, Colmol operator, into the section with him. Price worked the previous shift and he serviced the continuous miners in the 4 north and 7 west sections between shifts. He had just returned from the 4 north section, and did not report any unusual condition or occurrence in these working sections.

Robertson entered the 4 north section about 5:45 p.m., and encountered Messrs. Parker and Scott, trip rider and motorman, respectively, who were removing material from the abandoned 6 east section. Scott and Parker were unloading recovered material from two flat cars along the 4 north haulage road. Robertson issued a few new instructions to these men and then proceeded to the 4 north loading head, where he conversed with the belt-head operators and a little later with other men at the 7 west loading head. However, he did not visit any of the working places in the

two working sections. He then went into the 6 east section and examined for methane in a few roof cavities, but gas was not detected. As he was leaving the 6 east section he encountered and issued more instructions to the recovery men who were entering the section for another load of material. He left the section about 6:40 p.m. for the west side of the mine to check on the men who were repairing the broken rail reported by the day shift mine manager. He left the main west about 7:30 p.m. for the bottom to eat his lunch. Robertson testified later that all times stated were estimated, because he did not remember looking at his watch the entire evening. While eating his lunch he tried to contact the 4 north section by telephone to learn if they needed anything and to find out the amount of coal mined. After receiving no answer from the belt-head operators in the 4 north section, he began to get worried. His first surmise was that the telephone line was broken along the haulage road by spalling rib coal.

Robertson left the bottom in his locomotive about 8:05 p.m. and while traveling cautiously toward the 4 north section checked the telephone line for possible breaks. Upon reaching the 4 north entries, he noticed that the red signal lights were on, which meant that the trip should be coming out. After waiting a few minutes and not hearing any trip coming out of the 4 north, he continued to travel slowly toward the section. He proceeded inby the overcast at the 4 north and noticed a little dust in suspension. Advancement into the 4 north area revealed increasing amounts of debris and dust which convinced him that an explosion had occurred in this section. He left his locomotive near 2 west and walked along the

4 north haulage road toward 6 east, a distance of about one-half mile. About 150 feet outby 6 east, near a locomotive and two flat cars, he found the bodies of Scott and Parker. Excessive dust in the air at 6 east made visibility very poor but he noted that the door to this section was open or blown away and about 50 feet inby 6 east switch he found a scorched trolley guard. He traveled inby 6 east to the 7 west, called out a few names and not receiving any answers was convinced that none of the men in the 7 west and 4 north sections were alive. He returned immediately to his locomotive and traveled to the north-west angle entries where he cut off all the power to the 4 north section. He tried to use the telephone near the junction of the 4 north and the north-west angle entries to call the surface but the line was dead. Robertson returned to the bottom about 9:30 p.m. and immediately called the night storekeeper on the surface and informed him of the explosion and told him to notify all the company officials, and the State and Federal coal-mine inspectors.

Immediately after notifying the surface Robertson called the main west sections and ordered all men therein to return to the surface at once.

Leo Sanquenetti, main-line trip rider in the main west section and Mine Safety Committeeman, testified that about 7:30 p.m. they were coming out with a trip of cars and encountered dust in suspension near and at the north-west angle entries on the main west. The dusty atmosphere appeared to be clearing when he looked down the angle entries as his trip went by the intersection. He did not hear any noise, and assumed the dust was thrown into suspension by an empty derailed car on a trip traveling

toward the 4 north section. Another loaded trip of coal was transported to the bottom by the main west, main-line locomotive after 7:30 p.m. and an empty trip was taken into the 1 east, 3 north, main west when Sanquenetti while waiting at the belt head was informed by Robertson to contact the section foreman immediately and have him arrange to remove the men from the mine at once.

Scott and Parker were recovering material from the abandoned 6 east section off the 4 north. A load of material was being placed at various wide locations along the 4 north haulage road at the time of the night mine manager's visit. Apparently another trip had been made to and from the 6 east section and the recovery men were unloading material from the flat top cars when the explosion occurred. To reach the 6 east section from the 4 north haulage road, it was necessary to go through a door, which, according to the mine manager's testimony, was closed when he left the section, and it was demolished by the explosion. If this single, self-slamming door were latched open, the air would have been short-circuited from the 4 north working section, which would have permitted gas to accumulate in the 4 north Right "B", and 8 east Right "A" entries. An air lock had been provided in this section at the time of the last inspection but during material recovery operations the inby door of the air lock had been removed.

A section foreman and 8 men were working in the 4 north section on the 4:00 p.m. to midnight shift. This was only the second coal-producing shift worked in this section for the past 10 working days, because

the equipment was used to develop the 4 north and 8 west sections alternately and was moved into the 4 north from the 8 west during the midnight to 8:00 a.m. shift. The day shift developed the 4 north Right "B" entry approximately 66 feet and then retreated and developed the 8 east Right "A" entry off the 4 north Right "B" entry about 60 feet. The 4:00 p.m. shift advanced the 8 east Right "A" entry an additional 25 feet and then returned to advance the 4 north Right "B" entry about 14 feet. The foreman on the 4:00 p.m. shift was instructed orally and in writing by the day shift foreman to move the continuous mining unit at the start of the shift into the 4 north Right "A" entry to prepare this working face after driving the crosscut through to the Right "B" entry for experimental blasting tests. The adopted procedure at this mine was for the day shift section foreman to issue the proposed daily development instructions to the second shift section foreman, but the instructions were not followed.

Normal practice in producing coal in the 4 north entries was for the continuous miner to discharge the coal onto the floor or directly into the loading machine. The coal was then loaded into shuttle cars, which unloaded onto a belt that discharged into regular mine cars. When the explosion occurred, coal was not being mined in the 4 north Right "B" entry. The continuous miner had been backed out of the 14-foot box cut made in the 4 north Right "B" entry, and the operator and his helper were apparently changing bits, because bits and tools for changing them were observed in and near a tool box at the front of the continuous miner. An empty loading machine and shuttle car were directly behind the continuous miner and another

empty shuttle car had back switched or was in the act of back switching into the 4 north Right "B" entry. This shuttle car was forced or moved a short distance down the entry. All the controls of the face equipment were in the "off" position. The bodies of all the victims were found lying face down and all were headed in the same direction, away from the face area. The continuous-miner operator and his helper were the only victims that were not burned seriously and both died from lack of oxygen or from inhaling hot gases. The section foreman was apparently eating his lunch in the 4 north Left "A" entry and the electrician was found about 140 feet outby the section foreman in the same entry. There was coal on the 4 north belt conveyor and 10 cars were loaded with coal; eight were in the 4 north Left "A" entry and two were in the slant crosscut between the 4 north and 4 north Left "A" entries. A 13-ton locomotive was in front of the 8 loaded cars. Ten-car trips were usually hauled to the bottom from this working section, and since the required number of cars were loaded, the trip was about to be assembled and hauled to the bottom. The motorman was found about 10 feet from his locomotive in the slant crosscut between the locomotive and the belt head, and the trip rider was found in the third crosscut, about 200 feet outby the motorman. The belt-head operator was located about 60 feet outby the belt head. (Appendix C)

Two separate splits of air ventilated the 4 north entries, and according to the last reported weekly air measurements taken in this section, each split contained approximately 13,000 cubic feet of air. The air was normally directed to the working faces by line curtains, but the

line curtain used by the day shift in the 8 east Right "A" entry was taken down when the continuous mining unit moved out and into the 4 north Right "B" entry. A line curtain was later found badly burned and blown against the shuttle car and loading machine in the 4 north Right "B" entry. Removal of the line curtain from 8 east Right "A" created a dead end that could not otherwise be ventilated and would permit gas to accumulate. And if the 6 east door were latched open the air would be short-circuited from the right side of the 4 north entries permitting gas to accumulate in the 4 north Right "B", and 8 east Right "A" entries. There was evidence of gas burning at and near the junction of the 4 north Right "B", and 8 east Right "A" entries, indicating that the gas had reached explosive proportions at this point. The highest methane content obtained through analyses during the last three Federal inspections at the bottom of the No. 2 upcast shaft was 0.07 percent. The air from the 4 north section returns to the surface through this shaft. Approximately $5\frac{1}{2}$ hours after the explosion occurred, 0.50 percent methane was detected at the No. 2 upcast shaft on a W-8 methane detector or 7 times more than the highest reading obtained normally. Methane readings taken at half-hour intervals from about 1:00 a.m. to 7:00 a.m. on March 3, 1961, or from $5\frac{1}{2}$ to $11\frac{1}{2}$ hours after the explosion, ranged from a high of 0.50 to a low of 0.25 percent.

Methane may have also been released into the 4 north working section from the worked-out Nos. 4 and 3 coal seams which are located below the No. 5 seam. Occasionally, subsidence has occurred in some of the working sections off the 4 north entries and methane had been found

infrequently in these subsidence areas. There was evidence of subsidence in the 4 north Right "A" and "B" entries where a fall of roof 3 feet high occurred in the last open crosscut between the 4 north Right "A" and "B" entries. After the explosion, during recovery work and during the investigation, the roof continued to fall and work even after the area was heavily timbered. The roof coal near and outby the working face areas had drawn away from the roof and there was a definite depression in the floor in the 4 north Right "A" and "B" entries, which has proved to be a true indication of subsidence.

There were only two flame safety lamps found in the 4 north working section. The section foreman's lamp was damaged and was found near his body, and the other with a broken glass chimney and standards was hanging on the continuous miner. It was reported that the lamp found on the Colmol had been taken into the mine the previous Monday, and was damaged that day and not removed from the mine.

Acetylene and oxygen tanks were found about 200 feet outby the face of 4 north Right "A" entry. During the investigation it was at first believed that the gas ignited in the 4 north section may have been acetylene from the tank found in this entry. However, it was learned that both tanks were empty when stored outby the second crosscut behind the check curtain in the 4 north Right "A" entry.

A section foreman and 8 men in the 7 west section off the main north were performing normal coal-producing duties when the explosion occurred. During the preceding shift the continuous mining unit had worked slabbing pillars in No. 2 room off the 7 west Left "A", and when

the roof began to work they pulled out and moved their equipment into 7 west entry. They advanced approximately 60 feet and worked up to the end of their shift in this entry. At the end of the shift the continuous miner was backed to the last open crosscut in the 7 west entry where it was left for the man who services the continuous miner between shifts. The 4:00 p.m. shift started working in the 7 west Right "A" entry and advanced about 71 feet, with the last 28 feet being a box cut, when the explosion occurred. The continuous miner and loading machine controls were found in the operating position, and the Colmol continued to run until the night mine manager disconnected the alternating current from the affected section at the generating room near the intersection of the 4 north and north-west angle entries about 1½ hours after the explosion. Very fine coal was found piled on the floor to the roof back of the continuous miner, with only small openings on each side of the deposited coal. Most of this coal was apparently mined between the time of the explosion and the time the power was cut off the section. About 10 hours after the explosion the continuous miner was still hot when touched by hand and the face area was also very warm. The loading-machine operator was apparently moving his machine away from the continuous miner either to permit the operator to back out of the box cut or clean up the coal and coal dust that accumulated outby the face area. The loading machine boom was rammed into the right side of the shuttle car. There was coal on the conveyor of the loading machine, but the shuttle car was empty. Another loaded shuttle car was enroute to the belt and was found in the

second crosscut outby the face of the 4 north Right "A" entry. The conveyor belt was empty and 5 cars of the 10-car trip were loaded with coal and the sixth car was under the belt head and was partially loaded on the 4 north Left "A" entry.

The six men in the 7 west Right "A" entry were found within a few feet of one another between the last two open crosscuts. Apparently they had been moving away from the face area and were lying on their stomachs with hands trying to protect their faces. The jerryman was found in the 7 west entry about 60 feet outby the loaded shuttle car he was operating as relief driver during the regular driver's lunch period. The belt-head operator and the recently relieved shuttle-car operator were located 40 and 150 feet, respectively, outby the 7 west belt head on the 4 north Left "A" entry. (Appendix C)

The 4 north left split ventilated the 7 west section and according to the foreman on the previous shift the air was traveling in its normal course. A line curtain had been used to ventilate the 7 west working face but a line curtain was not used on the 4:00 p.m. shift to ventilate the 7 west Right "A" face.

Only one flame safety lamp was found in the 7 west working section; it was attached to the belt of the section foreman. Methane had not been detected on the previous shift by the section foreman. Tests for gas are normally made by the foreman in this section at about 20- or 30-minute intervals, providing no difficulties are encountered to keep him from the working faces.

There were no survivors in the 4 north working section of the mine and the remaining 33 men that were working in the main west section and around the slope bottom left the mine or remained to assist with recovery operations.

The explosion destroyed three concrete-block and 21 wooden stoppings, 4 wooden doors, and about 10 canvas curtains. Trolley and power wires, telephone line and water line were damaged, a roof-bolting machine was demolished and the 4 north and 7 west belts were badly damaged. Only minor damage was done to the face equipment and to other miscellaneous mining equipment. The damage caused by the explosion was confined mostly to the equipment and material in the 4 north and 4 north Left "A" entries.

The explosion resulted in loss of production from the entire mine from March 2, until March 13, when all working sections except the affected 4 north off the north-west angles were permitted to resume operations by the Director of the Bureau of Mines. The Director released 7 west, off the 4 north off the north-west angles on March 24, and finally permitted the entire mine to resume operations on March 28, 1961.

Recovery Operations: Stewart Johnson, underground superintendent, arrived at the mine about the same time the men from the main west working section reached the surface. After ordering several men to check the two mine fans, he organized a rescue party consisting of the two section foremen from the main west and 4 other workmen. They went underground about 10:10 p.m. and traveled by locomotive to the intersection of the 4 north

and north-west angle entries. All stoppings were intact up to the 6 west working section, and a temporary brattice-cloth stopping was erected at the 6 east to replace the demolished door. Additional rescue workers joined the initial party, ventilation was reestablished without difficulty, and all bodies were removed within 12 hours of the time the explosion occurred. During the recovery work in the 7 west and 4 north working sections, methane was not detected with permissible flame safety lamps and only traces of carbon monoxide were found with a carbon monoxide tester when the ventilation was reestablished in both working sections. Due to the adequate quantity of air directed into the 4 north entries, all recovery work was performed without the use of respiratory protective equipment. The only roof fall and dangerous roof encountered in the entire explosion area was in the last open crosscut between the 4 north Right "A" and "B" entries, and the roof was known to be dangerous in this area prior to the explosion.

INVESTIGATION OF CAUSE OF EXPLOSION

Investigation Committee: The underground investigation of the cause of the explosion was begun on March 4, 1961, and completed April 14, 1961. Members of the official investigation committee were:

Indiana Bureau of Mines and Mining

Hobert P. Butler	Commissioner of Labor
Charles A. Purcell	Director
William H. Sharp	Inspector
Roy E. Hudson	Inspector

Viking Coal Corporation

Birch Brooks	Vice President and General Manager
C. B. Burk	General Superintendent and Mining Engineer
Stewart Johnson	Superintendent
Jesse Shepperd	Mine Manager (Mine Foreman)
Ray Biggs	Electrical Engineer
Morris Adams	Chief Electrician
Nathaniel Kirk	Advisor

United Mine Workers of America

Charles Ferguson	Director, Safety Division
Rex Lauck	Assistant Editor, United Mine Workers Journal
Louis Austin	International Board Member
Ernest Goad	President, District 11
William Clark	Safety Committeeman, Viking Mine
Leo Sanquenetti	Safety Committeeman, Viking Mine

Lynch Coal Operators Reciprocal Association

Fred Conrad	Inspector
Bert McCray	Inspector

United States Bureau of Mines

James Westfield	Assistant Director--Health and Safety
F. J. Smith	District Supervisor
C. M. Dovidas	Federal Coal-Mine Inspector
S. J. Douglas	Federal Coal-Mine Inspector (Electrical)

Many other representatives of the afore-mentioned organizations participated in the different phases of the underground investigation of the disaster. Bureau of Mines representatives included: Messrs. J. A. McCune, Frank Perz, R. W. Whittaker, and Louis Lorenzo.

Charles Purcell, Director of the Indiana Bureau of Mines and Mining, conducted an official hearing on the investigation of the explosion by interrogating a number of officials and employees of the company at the

Vigo Circuit Courtroom, in the Vigo County Court House, Terre Haute, Indiana, March 9, 1961. The purpose of the hearing was to hear and record all testimony relevant to conditions and practices in the mine prior to and on March 2, and to determine therefrom, if possible, the cause of the explosion. Some of the information thus obtained is included in this report. Representatives of the operating company, United Mine Workers of America, Indiana Bureau of Mines and Mining, and U. S. Bureau of Mines questioned the officials and employees during the hearing.

Methane as a Factor in the Explosion: The mine is classed gassy by the Indiana Bureau of Mines and Mining and by the Bureau of Mines, and methane has been detected in the mine on several occasions with a permissible flame safety lamp. During the three Federal inspections completed in April, August, and December 1960, the mine was liberating methane at a calculated rate of 172,000, 293,000, and 151,000 cubic feet, respectively in 24 hours. During the December 1960 inspection, the immediate return air from the right split of the 4 north section taken at 6 east contained 0.09 percent methane in 28,000 cubic feet of air.

Testimony of company officials and employees during the investigation indicated that gas had not been detected during the

previous shift, and the last time methane was recorded being found in the 4 north was in No. 7 room off the 6 west Left "A" entry in October 1960. During recovery operations methane was not detected at any time in the 4 north and 7 west working sections. However, small percentages of methane were detected on top of roof falls in the abandoned 6 and 7 east sections, and the highest concentration found with a W-8 methane detector was 2.50 percent on top of a 15-foot fall in the abandoned 6 east section in Room 21.

Line curtains were used generally in the 4 north and 7 west working sections, but during the investigation it was learned that occasionally the line curtains were not kept up to the continuous miner and it was necessary for the operator to stop the continuous miner and extend the curtain. Also on a few occasions, the continuous miners had to stop mining, when coal was piled behind the machines, seriously curtailing the flow of air to the working faces.

Fragile, globular coke droplets adhering to the roof and ribs, indicative of slow burning gas, were found at and near the intersection of 4 north Right "B", and 8 east Right "A" entries. Soot streamers were found on the return air side in the third crosscut between 4 north Left "A" and "B" entries outby the working faces, and in the abandoned 7 east

section in Rooms 2, 3 and 10 off the 7 east Left "B" entry. The aforementioned evidences of burning gas were not found at any other location within the explosion area.

Unquestionably, the disaster resulted from an ignition of methane that had accumulated when the line curtain was removed from the 8 east Right "A" entry, or as a result of short-circuiting the air current by latching open the 6 east door. Closing the door would reestablish the ventilation and the methane moving out of the working places could have been ignited by an arc, spark, or open flame. It is possible that methane might have been released in an unusually large quantity from the coal, floor or roof due to subsidence in the above-mentioned working areas. It is known that methane has been detected occasionally under similar conditions in the past, and the 4 north entries are above the worked-out and abandoned Nos. 4 and 3 seams, which had been mined by another company (see Appendix D). The vertical distance between the Nos. 5 and 4 seams is about 105 feet and the distance between the Nos. 4 and 3 seams is approximately 65 feet. An air sample collected at the 6-inch surface discharge line used to remove the water from the No. 3 seam contained 32.8 percent methane, which could create an explosive methane-air mixture if united with the mine atmosphere.

A special investigation was conducted by Bureau of Mines engineers and technicians to determine the methane concentrations being liberated during continuous mining operations in the 4 north and 7 west working sections. Continuous records were taken throughout ten shifts in 7 west

from March 27, through March 31, 1961. The concentrations of methane at the machine while it was in operation reached approximately 2.50 percent maximum, the highest being attained when the Colmol was near the end of a crosscut and before breaking through. The results throughout the tests were consistent, and the concentrations increased when the machine started cutting and decreased as soon as it stopped. Readings taken with methane detectors at the solid face immediately after the Colmol had been pulled back were never higher than 0.60 percent and usually were 0.30 to 0.40 percent. The concentrations in the return from the 7 west section reached a maximum of 0.125 percent. The maximum volume of air to the 7 west section was 14,400 cubic feet a minute, and would indicate a maximum liberation rate of approximately 18 cubic feet of methane a minute.

The investigation was continued in the 4 north section from April 6, to April 14, 1961, during which period there was also development in the 9 west section. The 4 north and 4 north Right "A" entries were driven just beyond the 8 east Left "A" and the 8 east section was developed considerably because this was the area in which subsidence had occurred. Particularly bad roof was encountered in the 8 east (center) entry, as had been expected. Once this area had been passed the roof condition improved and development proceeded rapidly. The maximum concentration of methane recorded in the 4 north, 9 west and 8 east sections, was 1.00 percent. The concentration in the return was never greater than 0.04 percent. The maximum air reading to these sections was 17,880 cubic feet a minute, which would indicate a maximum liberation rate of 7.15 cubic feet of methane a minute.

Flame: Evidence of heat and flame, in the form of coke, soot or partly burned paper, canvas, and wood, was observed in the 4 north and 7 west working sections, in the temporarily idle 8 west section, in the abandoned 7 east section in rooms 1 to 8, inclusive, and in the 4 north and 4 north Left "A" entries from the face regions and extending to the switch for the 6 east section. With the exception of the continuous-miner operator and his helper in the 4 north working section, all the victims' bodies were badly burned.

A total of 43 mine dust samples was collected after the explosion starting at an imaginary line across the six entries of the 4 north set at 5 west (see Tables 2 and 3 and Appendix C). The results of analyses for incombustible content and tests for coke in the mine dust samples are shown in Tables 2 and 3. The presence of coke in the mine dust samples is one of the criteria by which extent of the flame was fixed, even though it is possible that such coke in the outby end of the 4 north set of entries may have been blown there. Thirty-two of the 43 samples collected contained coke ranging in quantities from traces to small particles, and only one sample taken off the roof in the 4 north Right "B" entry contained a large amount of coke. None of the other 10 samples contained coke. Coke was plastered on the roof and ribs in the 8 west entries and in room 2 off the 8 west Left "A" entry, and in the 4 north, 4 north Left "A", Right "A" and "B" entries near 4 north working section and intermittently on roof, ribs and equipment in 4 north and 4 north Left "A" entries from the working section to the 6 east switch. Extremely heavy coke was also plastered in the abandoned 7 east section in rooms 2, 3 and 4 off the 7 east Left "A" entry.

Forces: Difficulty was not experienced in discerning the direction of forces. Coking and evidence of slow burning gas were on the roof, ribs and equipment at and near the intersection of the 4 north Right "B", and 8 east Right "A" entries and the emanation of forces was from this area outward and extending to about 250 feet outby the 5 west in the 4 north and 4 north Left "A" entries. The forces spread right and left into the temporarily idle 8 west section, the 7 west working section, the abandoned 7 east to about room 14, including the 14 rooms off 7 east Left "A" entry, and into the abandoned 6 east entries to about room 8. Evidence of extreme violence was observed at the tail of the belt when the anchored belt tail was moved outby 27 feet, at the crosscut leading to the 8 west entry where the new roof drill was found completely demolished, along the belt in the 4 north entry, at the 6 and 7 east doors, at the 7 west belt, and along the 4 north Left "B" and "C" entries between 7 and 8 west where bark stripped from inby posts was found wrapped around outby posts. Most of the forces were traveling in a southerly direction after leaving the 4 north working section and after entering and leaving the abandoned active and temporarily idle working section.

Only three concrete-block stoppings were blown out; the two near the working sections were blown toward the intake air course and the stopping at 6 west was blown toward the return air course. Practically all the wooden stoppings in the 4 north Left "B" and "C" and Right "A" and "B" that were used to direct the air into the panel entries were also blown in a southerly direction.

Probable Point of Origin: The consensus of the Bureau of Mines investigators is that the explosion originated at or near the junction of the 4 north Right "B", and 8 east Right "A" entries.

Factors Preventing Spread of Explosion: The areas affected by the explosion are shown on the mine map (Appendix B). The diluting and quenching effect of the rock dust applied was the principal factor in preventing further spread of the explosion. Other factors acting in combination that helped limit the explosion area were: The cooling effect of the extensive rib, roof, and floor surfaces of the numerous entries in the path of the explosion; and ample open areas for expansion of forces, resulting in reduction of flame speed and temperature.

Summary of Evidence: Conditions observed in the mine during recovery operations and the investigation following the disaster, together with information available from previous Federal coal-mine inspection reports and that obtained from company officials, workmen, and mine records, provided evidence as to the cause and the point of origin of the explosion. The evidence from which the conclusions of the Federal investigators are drawn is summarized as follows:

1. Records of the preshift or foreman's examinations of all working sections indicated no unusual condition.

2. The Indiana No. 5 coal bed in the area is "gassy", and normal mining operations cause liberations of methane at working faces. Generally, the greatest liberation of methane occurs when the continuous miner is operating.

3. The continuous mining unit in the 4 north working section had been engaged in production of coal shortly before the explosion occurred; however, no coal was being mined at the time.

4. The continuous-miner operator's lamp was found on the Colmol with the glass chimney and two standards broken and the foreman's lamp was found near his body along the haulage road.

5. The ventilating current on the right side of the 4 north working section could have been interrupted completely for an estimated period of at least one hour just prior to the time of the explosion, which would permit methane to accumulate at the faces of 8 east Right "A" and/or 4 north Right "B" entries.

6. Line curtains were not always maintained up to the continuous miner, and the line curtain that was used in the 8 east Right "A" entry was removed when the continuous miner was returned to further develop the 4 north Right "B" entry an additional 14 feet.

7. The dangerous roof in the last open crosscut between 4 north Right "A" and "B" entries was definitely established as one of the signs that subsidence occurred in these entries. The roof coal drawing away from the roof, and the depressions in the floor were also acceptable signs that subsidence had occurred.

8. Methane may or may not have been liberated from the underlying mined out Nos. 4 and 3 coal seams when the subsidence occurred.

9. All forces emanated from the junction of the 4 north Right "B", and 8 east Right "A" entries.

10. The inby door of the air lock in the 6 east section was removed during material recovery operations which would short-circuit the air from the right side of the 4 north working section if the remaining door at 6 east were latched open.

11. Permissible and nonpermissible equipment was used in the 4 north working section, but the permissible loading machine and continuous miner were found in a nonpermissible condition when examined after the explosion. The nonpermissible shuttle cars had numerous openings into arcing electrical components, and all the equipment was capable of igniting gas.

12. Matches, lighters, and cigarettes were listed among the personal effects found on victims of the explosion, and 2 packs of cigarettes and a lighter were found in the mine after the explosion. Fourteen of the 22 victims had either lighters, cigarettes or matches and eight had lighters and cigarettes. Smoking underground evidently was common practice, and management did not have a searching program to assure that smokers' articles were not carried into the mine.

13. Fragile, globular particles of coke that would be indicative of slow burning gas were found adhering to the roof and ribs around the intersection of 4 north Right "B", and 8 east Right "A" entries.

14. Plastered coke was observed in 8 west, and soot and thick deposits of fused coal particles were plastered on the inby sides of timbers in rooms off 7 east that were exposed to the explosion force coming out of 4 north.

15. Inadequate rock dusting of the 4 north face regions, especially the last open crosscuts, no rock dust applied in 8 east or 8 west entries, coal and coal dust on and along the 4 north belt conveyor and the loaded cars on 4 north Left "A" made available ample fuel to propagate an explosion.

16. Coal in the loaded cars to the north of 7 west loading head on 4 north Left "A" entry, normally piled 12 to 14 inches above the top of the cars was swept away to a similar depth below car level on the inby or north end and about car level on the outby or south end.

Cause of Explosion: The Federal investigators are of the opinion that the disaster was caused by the ignition of an accumulation of methane at the junction of the 4 north Right "B", and 8 east Right "A" entries of the 4 north section off the north-west angle entries. Gas had accumulated in the recently mined faces when normal ventilation was disrupted by latching the single door open at the entrance to 6 east section for a prolonged period of time and/or removing the line curtain from 8 east Right "A", or was encountered in an unusually large quantity when mining in a subsidence area. The gas was ignited by an arc or spark from any piece of the electrical equipment in the vicinity or by an open flame. Coal dust in the immediate area entered into the explosion, which then picked up all the fuel necessary for propagation from the coal left on the belt line, the loaded mine cars and the heavy accumulation of coal and coal dust in the 8 west section that had never been rock-dusted.